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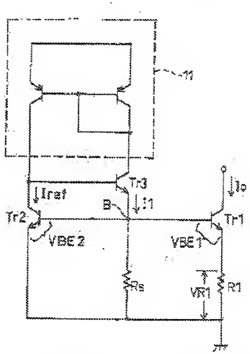
(71)Applicant : SHARP CORP
(72)Inventor : ONISHI MASAYA

(54) CONSTANT CURRENT GENERATING CIRCUIT

(57)Abstract:
PROBLEM TO BE SOLVED: To effectively reduce temperature dependency of output currents in a constant current generating circuit.
SOLUTION: The bases of an output transistor Tr1 and a voltage reference transistor Tr2 are connected to each other, and the mutual emitters are connected to GND, and a resistor Rs is connected between the bases and emitters of the output transistor Tr1 and the voltage reference transistor Tr2. Also, a temperature compensating resistor R1 is connected between the emitter of the output transistor Tr1 and the GND as a first temperature compensating element.



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CLAIMS

[Claim(s)]
[Claim 1] The constant-current generating circuit characterized by to be prepared the 1st component for temperature compensation between the emitter of the above-mentioned transistor for an output, and GND in the constant-current generating circuit where the base of the transistor for an output and the transistor for electrical-potential-difference criteria was connected mutually, each emitter of both the above-mentioned transistors was connected to GND, and resistance Rs was connected between the base of the above-mentioned transistor for an output, and the transistor for electrical-potential-difference criteria, and an emitter.
[Claim 2] The constant current generating circuit according to claim 1 where the component for temperature compensation of the above 1st comes to carry out parallel connection of two or more resistance of the same configuration as the above-mentioned resistance Rs, and is characterized by adjoining the above-mentioned resistance Rs and being arranged.
[Claim 3] The constant current generating circuit according to claim 1 or 2 characterized by preparing the 2nd component for temperature compensation between the emitter of the above-mentioned transistor for electrical-potential-difference criteria, and GND.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the constant current generating circuit used for light-receiving amplifiers, such as DVD, CD-ROM, CD-R, and a pickup system for CD-RW, etc.
[0002]
[Description of the Prior Art] The light-receiving amplifier is used for DVD, CD-ROM, CD-R, and the pickup system for CD-RW. Also in this, a current DVD-ROM commercial scene has a 10X DVD-ROM pickup system in use, and the pickup manufacturer of several companies is furthering

development of 16X DVD-ROM. From now on, it will be expected that especially a DVD commercial scene progresses towards improvement in the speed further. For this reason, much more improvement in the speed of the light-receiving amplifying circuit for pickup is needed.
[0003] The block diagram of the light-receiving amplifying circuit for pickup is shown in drawing 3 . The light-receiving amplifying circuit for pickup shown here consists of constant current generating circuits 105 which carry out bias of all of the current potential conversion circuit 102 connected to the photodiode 101 which receives signal light, and the photodiode 101, the reference circuit 103, the differential circuit 104 which amplifies further the voltage signal changed by the current potential conversion circuit 102, and said circuit.
[0004] It is as follows when the principle of operation of the light-receiving amplifying circuit for pickup of drawing 3 is explained.
[0005] Electrical-potential-difference conversion of the signal current Ipd which the reflective signal light of CD or a DVD disk inputted into the photodiode 101, and was generated is carried out by feedback resistance Rf of the current potential conversion circuit 102, when the signal current Ipd flows in the direction shown by the arrow head of drawing 3 , the output potential point A of the current potential conversion circuit 102 goes up, noninverting magnification is further carried out by the latter differential circuit 104, and output voltage Vo produces it. Vs is a fixed electrical potential difference supplied from the outside here, and electrical-potential-difference transformation when the signal current Ipd arises is expressed as follows.
Vo=Rf-Rb/Ra-Ipd (1)
Moreover, as shown in the block diagram of drawing 3 , when the constant current generating circuit 105 supplies the bias current of all amplifying circuits and the output current of the constant current generating circuit 105 changes with change of ambient temperature, as shown in drawing 6 , property fluctuation of the light-receiving amplifying circuit for pickup arises. Among drawing, Curves a, b, and c are cases smaller than always [forward], respectively, when larger [the output current of a constant current generating circuit is normal, and] than always [forward]. For this reason, it is necessary to design the output current of a constant current generating circuit so that it may not be dependent on ambient temperature infinite.
[0006] As mentioned above, improvement in the speed is progressing and, as for the light-receiving amplifying circuit for pickup, development of the high accumulation high-speed process for it is performed. In a high-speed process, an important element is reduction of the parasitic capacitance which accompanies components, such as a transistor and resistance.
[0007] Next, the stabilization to the temperature of the output current of the constant current generating circuit in the process which reduced the parasitic capacitance which accompanies a resistance element is described.
[0008] An example of the constant current generating circuit of the conventional type in a process is conventionally shown in drawing 4 . With this configuration, transistors Tr51, Tr52, and Tr53 are formed. the boron a P type single crystal semiconductor temperature resistance coefficient and whose sheet resistance (omega/**) (** expresses the geometric square (unit area) of a conductor) main resistance is conventionally formed with the P type single crystal semiconductor in the case of the process, and are impurities -- an injection rate -- **** -- it is determined. Moreover, when this semi-conductor resistance has the temperature coefficient of plus and the injection rate of boron is made [many] (i.e., when the temperature resistance coefficient at the time of making sheet resistance small fell and the injection rate of boron is lessened conversely), sheet resistance becomes large and a temperature coefficient also becomes large. The molecular motion in a semi-conductor is activated by the temperature rise, and the temperature coefficient of this plus is because migration of a carrier, i.e., the poured-in boron, is controlled. Although it is also possible on an actual circuit design to lower sheet resistance and to use low resistance of a temperature coefficient, in order to obtain strong resistance of resistance by low sheet resistance, it will be necessary to lengthen the configuration of the resistance element in a chip extremely. Moreover, it is a negative factor on circuit improvement in the speed for the parasitic capacitance by the depletion layer formed of a PN junction between the P-type semiconductor of resistance and an N type epitaxial layer to accompany in such semi-conductor resistance, and to enlarge the configuration of a resistance

element.

[0009] In consideration of the above-mentioned contents, the resistance which has a temperature coefficient around +3000 ppm/degree C is conventionally used in the process. Here, a temperature resistance coefficient is carried out in +3000 ppm/degree C, and how to acquire the stability over the temperature of the output current of the constant current generating circuit of a conventional type is explained below. In the field 112, the pyrovoltage (Vt) temperature coefficient of +3300 ppm/degree C is performing temperature compensation in the constant current generating circuit of the conventional technique in a process conventionally which is shown in drawing 4 , and the temperature coefficient of the output current Io in this case and the output current is VBE2=VBE1+Rs-I1. (2)

Vt-ln(Iref/Is) =Vt-ln[I1/(I0, Is)]+Rs-I1 (3)

Since it is Iref=I1=Io, it is Io=Vt-ln10/Rs. (4)

Here, it is the amount T:absolute temperature Is of Vt=(kxT)/qk:Boltzmann's-constant q:electronic charge :P It is the saturation current of N junction. In addition, "delta" expresses differential.

[0010] 1/Io-delta Io/delta [of temperature coefficients] T of the output current Io is deltaIo/deltaT=delta(Vt-ln10/Rs) /deltaT from a formula (4). (5)

= Vt-ln10/Rs and [1-/Vt- (deltaVt/deltaT)

- 1-/Rsand(deltaRs/deltaT)] (6)

= Io and [1-/Vt- (deltaVt/deltaT)

- 1-/Rsand(deltaRs/deltaT)] (7)

Therefore, 1-/Io-delta Io/delta T=1-/Vt- (deltaVt/deltaT)

- 1-/Rs- (deltaRs/deltaT) (8)

It becomes.

[0011] The pyrovoltage (Vt) temperature coefficient of +3300 ppm/degree C and the temperature resistance coefficient of +3000 ppm/degree C are offset, and it is temperature coefficient =+3300ppm/degree C of the output current Io. - (+3000 ppm/(degree C))

= +300 ppm/degree C (9)

It becomes. Here, the active load 111 of drawing 4 is a circuit for obtaining I1=Io, and plays a role with the same said of the active load in the constant current generating circuit shown after this.

[0012] As mentioned above, for improvement in the speed of an amplifying circuit, reduction of the parasitic capacitance which accompanies semi-conductor resistance is important, and the case where a semi-conductor temperature resistance coefficient is subtracted has arisen in the high-speed process development aiming at parasitic capacitance reduction. This is because P-type semiconductor resistance is formed with polycrystalline silicon.

[0013] Since crystal grain is small compared with P type single crystal silicon, an extreme PN junction is not formed between N type epitaxial layers, and, as for polycrystalline silicon, parasitic capacitance does not accompany. Moreover, also in P type polycrystalline silicon semi-conductor resistance, although it is possible to change sheet resistance and a temperature coefficient with the injection rate of boron like the case of P type single crystal silicon, the behavior of the grain boundary becomes dominant from the inside of crystal grain, i.e., the single crystal section, and a P type polycrystal semi-conductor silicon temperature resistance coefficient has the temperature coefficient of minus.

[0014] The constant current generating circuit which controlled change of the output current over a temperature change here considers the P type polycrystalline silicon semi-conductor temperature resistance coefficient in a high-speed process as -1000 ppm/degree C. The example of a conventional-type constant current generating circuit in case a temperature resistance coefficient is minus here is shown in drawing 5 . With this configuration, transistors Tr61, Tr62, and Tr63 are formed.

[0015] This circuit is a constant current generating circuit which used the electrical potential difference VBE between base-emitters for reference voltage, and the output current Io of this circuit is determined as follows by VBE2 of a transistor Tr62, and Resistance Rs. In addition, log is a common logarithm.

Io=VBE2/Rs (10)

Here, VBE2 is VBE2=Vt-ln (Iref/Is). (11)
Come out, and it is and is the energy gap of Iref=100microARs=7.78komegalog(Is) =-17 silicon. Eg=1.2V constant (4-a) It is set to VBE2=Vt-ln(Iref/Is) =778mV when referred to as =2T=300 KVt=kT/q=26mV (number-of-cases value count which is not special mention below is performed for the above-mentioned numeric value).
[0016] First, when it assumes that it is delta Iref/delta T= 0 and only the temperature characteristic (deltaIs/deltaT) of the saturation current Is is taken into consideration, it is deltaVBE2/deltaT=1/T [-Eg+VBE2- (4-a) and kT/q].
= -1.58mV/degree C (12)
Therefore (delta VBE2/delta T), /VBE2=-1.58 (mV/degree C) / 778 (mV)
= -2031 ppm/degree C (13)
It comes to be alike and the potential of Point A falls with the temperature coefficient of -2031 ppm/degree C.
[0017] The temperature coefficient of Io is delta Io/delta T=1-/Rs-deltaVBE2/deltaT-VBE2/(Rs-Rs) anddeltaRs/deltaT from a formula (10). (14)
It comes out, and it is and the temperature coefficient (deltaRs/deltaT) of resistance Rs / Rs is /Rs=-1000ppm/degrees C as mentioned above (deltaRs/deltaT). Therefore (deltaIo/deltaT), /Io= (delta VBE2/delta T)/VBE2 - (deltaRs/deltaT)
/Rs=-2031-(-1000) =-1031ppm/degree C (15)
It becomes.
[0018] Furthermore, although calculated as temperature coefficient delta Iref/delta T= 0 of Current Iref for convenience, the actual current Iref has the -1031ppm/degree C temperature coefficient, and is larger by the formula (13), than degree C in -1.58mV /. [of the temperature coefficient of VBE2] That is, the rate of a temperature change of VBE2 by fluctuation of the current Iref at the time of temperature T= immobilization and Is= immobilization (delta Is/delta T= 0) is deltaVBE2/deltaT=-0.026mV/degree C. (16)
It is at (the time of delta Iref/delta T=-1031ppm/degree C and delta Is/delta T= 0).
[0019] Thereby, the rate of a temperature change of VBE2 when taking into consideration the temperature coefficient of Current Iref and the temperature coefficient of the saturation current Is ('is attached) is deltaVBE2'/deltaT=-1.58+ (-0.026).
= -1.606mV/degree C (17)
A next door, therefore the temperature coefficient of VBE2 at this time become (deltaVBE2'/deltaT)/VBE2'=-1.606/778=-2064ppm/degree C. Therefore, the temperature coefficient of Io at this time becomes (deltaIo'/deltaT)/Io'=-2064-(-1000) =-1064ppm/degree C.
[0020] Therefore, when the temperature coefficient of Resistance Rs is -1000 ppm/degree C in the constant current generating circuit of the conventional type shown in drawing 5 , even if it compares the temperature coefficient of the output current Io with the temperature coefficient of +300 ppm/degree C of the conventional circuit in a process in that absolute value conventionally which is shown in drawing 4 , it is large, and it is difficult to control change of the output current Io over a temperature change in this constant current generating circuit system.
[0021]
[Problem(s) to be Solved by the Invention] When the change to the temperature of the constant current generating circuit output current is large, the stability of the property of the light-receiving amplifying circuit for pickup over a temperature change becomes is hard to be acquired. For example, when the ambient-temperature fluctuation to 25 degrees C to 85 degrees C is considered in the constant current generating circuit of the conventional type shown in drawing 5 mentioned above in -10 degrees C - +85 degrees C of operational temperature ranges of the light-receiving amplifying circuit for pickup, it is change of the output current Icc, i.e., the bias current of the light-receiving amplifying circuit for pickup. -1064ppm/degree-Cx(85-25) **/1 million=-0.064 (18)
It comes out, and it is and the bias current of an amplifying circuit will decrease 6.4% by the above-mentioned temperature change.
[0022] By this fluctuation, the offset voltage which is gain-response frequency characteristics and the difference of an external power Vs and output voltage Vo which are the main property of

the light-receiving amplifying circuit for pickup gets worse. The response frequency-characteristics wave of the light-receiving amplifying circuit for pickup is as having been shown in above-mentioned drawing 6 . When a bias current increases, the phase margin decreases by the increment in an opening loop gain of an amplifying circuit, and gain peaking arises. When a bias current falls contrary to this, the band of a response frequency becomes narrow and there is a problem to which a signal transduction possible frequency falls. For this reason, it is necessary to control temperature dependence of the output current of a constant current generating circuit as much as possible. The temperature coefficient of the output current of a constant current generating circuit has ideal degree C in 0 ppm /.
[0023] This invention is made in view of the above-mentioned trouble, and the purpose is in offering the constant current generating circuit which can decrease the temperature dependence of the output current effectively.
[0024]
[Means for Solving the Problem] In order to solve the above-mentioned technical problem, the constant current generating circuit of this invention The base of the transistor for an output and the transistor for electrical-potential-difference criteria is connected mutually. In the constant current generating circuit where each emitter of both the above-mentioned transistors was connected to GND, and Resistance Rs was connected between the base of the above-mentioned transistor for an output, and the transistor for electrical-potential-difference criteria, and an emitter It is characterized by preparing the 1st component for temperature compensation between the emitter of the above-mentioned transistor for an output, and GND.
[0025] By the above-mentioned configuration, the 1st component for temperature compensation is prepared between the emitter of the transistor for an output, and GND.
[0026] Therefore, the bias current of the transistor for an output, i.e., the output current, and the bias current of the transistor for electrical-potential-difference criteria become a mutually different value. Consequently, it comes to have the temperature coefficient (temperature dependence) from which the electrical potential difference between base-emitters of the transistor for an output (VBE1) and the electrical potential difference between base-emitters of the transistor for electrical-potential-difference criteria (VBE2) differ mutually. And each other is mutually offset by the temperature dependence of the electrical potential difference between base-emitters of each transistor, and the temperature dependence of the 1st component for temperature compensation, and temperature dependence of the output current can be made small as a whole.
[0027] So, the temperature dependence of the output current can be decreased effectively. In addition, when the above-mentioned resistance Rs has a negative temperature coefficient, compared with the former, it can be more remarkable and the temperature dependence of the output current can be decreased. That is, this invention can perform stabilization to ambient-temperature change of the constant current generating circuit output current in the above-mentioned light-receiving amplifying circuit for pickup.
[0028] Moreover, add to the above-mentioned configuration, and the component for temperature compensation of the above 1st comes to carry out parallel connection of two or more resistance of the same configuration as the above-mentioned resistance Rs, and the constant current generating circuit of this invention is characterized by adjoining the above-mentioned resistance Rs and being arranged.
[0029] By the above-mentioned configuration, the component for temperature compensation of the above 1st comes to carry out parallel connection of two or more resistance of the same configuration as the above-mentioned resistance Rs, and adjoins the above-mentioned resistance Rs, and it is arranged.
[0030] Therefore, when a value small as resistance of the component for temperature compensation of the above 1st is desired, it is not necessary to have such small resistance alone. Therefore, a general-purpose resistance element etc. can be used as a component for temperature compensation of the above 1st. Moreover, since the component for temperature compensation of the above 1st is a component of the same configuration as the above-mentioned resistance Rs, formation of the component for temperature compensation of the

above 1st is possible in the same manufacture process as Resistance Rs.
[0031] So, in addition to the effectiveness by the above-mentioned configuration, it can be an easy configuration, and can be accurate, and the temperature dependence of the output current Io can be reduced.
[0032] Moreover, in addition to the above-mentioned configuration, the constant current generating circuit of this invention is characterized by preparing the 2nd component for temperature compensation between the emitter of the above-mentioned transistor for electrical-potential-difference criteria, and GND.
[0033] By the above-mentioned configuration, the 2nd component for temperature compensation is prepared between the emitter of the above-mentioned transistor for electrical-potential-difference criteria, and GND. Therefore, the electrical potential difference of a sufficiently big value can be applied to the component for temperature compensation of the above 1st by having the 2nd component for temperature compensation.
[0034] So, even if it adopts a component with big resistance as a component for temperature compensation of the above 1st, it becomes impossible to interfere in addition to the effectiveness by the above-mentioned configuration, and the degree of freedom of an ingredient and the degree of freedom of designs (arrangement of a component etc.) can be extended.
[0035]
[Embodiment of the Invention] It will be as follows if one gestalt of operation of this invention is explained based on drawing 1 and drawing 2 .
[0036] Drawing 1 is an example of a constant current generating circuit which has the resistance R1 for temperature compensation as 1st component for temperature compensation concerning the gestalt of this operation.
[0037] The bases of the transistor Tr1 for an output and the transistor Tr2 for electrical-potential-difference criteria are connected, and the mutual emitter is connected to GND. Moreover, the resistance Rs which has a negative temperature coefficient between emitters is connected with the base of the transistor Tr1 for an output, and the transistor Tr2 for electrical-potential-difference criteria. And the resistance R1 for temperature compensation is formed as 1st component for temperature compensation between the emitter of the transistor Tr1 for an output, and GND. An A point is a node of the emitter of the transistor Tr1 for an output, and the resistance R1 for temperature compensation. B points are the base of the transistor Tr1 for an output, the base of the transistor Tr2 for electrical-potential-difference criteria, and a node of Resistance Rs. In the transistor Tr1 for an output, and the transistor Tr2 for electrical-potential-difference criteria, the emitter surface ratio is 1. Moreover, the transistor Tr3 is formed.
[0038] The active load 11 is a circuit for obtaining I1=Io like drawing 4 , as mentioned above. Two terminals of this are connected to the collector and the base of a transistor Tr3, and the base of this transistor Tr3 is connected to the collector of the above-mentioned transistor Tr2 for electrical-potential-difference criteria. The emitter of a transistor Tr3 is connected to the base of the transistor Tr1 for an output, and the transistor Tr2 for electrical-potential-difference criteria (it considers as a B point).
[0039] Here, in the configuration of drawing 5 , the resistance R1 for temperature compensation is produced using P type polycrystalline silicon semi-conductor resistance, and a temperature coefficient (delta R1/delta T) / R1 has become the same (delta R1/T[delta])/R1=-1000ppm/degree C.
[0040] In the case of the numerical example of the constant current generating circuit of the conventional type shown in drawing 5 mentioned above, the output current Io of the constant current generating circuit on the basis of VBE which does not have the resistance R1 for temperature compensation has a -1064ppm/degree C temperature coefficient.
[0041] On the other hand, with the gestalt of this operation, it has the resistance R1 for temperature compensation as 1st component for temperature compensation between the emitter of the transistor Tr1 for an output, and GND as mentioned above. When considering the 1st component for temperature compensation as the resistance for temperature compensation (R1) in this way, and by changing the resistance of this resistance R1 for temperature

compensation The bias current value Io and Iref of the transistor Tr1 for an output and the transistor Tr2 for electrical-potential-difference criteria are set as a different value. It is possible to control the temperature change of the output current Io by changing the temperature coefficient of VBE1 and VBE2 of the transistor Tr1 for an output and the transistor Tr2 for electrical-potential-difference criteria, respectively.

[0042] The currents Iref and Io of the constant current generating circuit of drawing 1 are Iref=VBE2/Rs, respectively. (19)

Io=(VBE2-VBE1)/R1 (20)

Come out, and it is and is VBE1=Vt-ln (Io/Is). (21)

It comes out.

[0043] As mentioned above, with the gestalt of this operation, it becomes possible to make it Iref!=Io by the resistance R1 for temperature compensation. When Iref and Io have the relation of Iref!=Io, the temperature coefficient of VBE2 and VBE1 is deltaVBE2/deltaT/VBE2 ! =deltaVBE1/deltaT/VBE1 from a formula (11), (12), and (21). (22)

It becomes. In addition, a notation "delta" expresses differential. That is, it becomes possible to distinguish between the temperature coefficient of the electrical potential differences VBE1 and VBE2 between transistor base-emitters when a temperature change arises by distinguishing between the current value of Iref and Io. In the constant current generating circuit of drawing 1 , temperature coefficient change of the output current Io is controlled using the temperature coefficient difference of VBE1 and VBE2 in which this adjustment is possible.

[0044] First, it is deltaVBE2/deltaT/VBE2=deltaVBE1/deltaT/VBE1 because of fundamental explanation of operation. (23)

delta Iref/delta VBE2=delta Io/delta VBE 1= 0 (24)

When it assumes, the electrical potential difference VR 1 between the points A and GND of the constant current generating circuit of drawing 1 is next formula VR1=VBE2-VBE1. (25)

It comes out, and it is expressed, and VR1 is not based on temperature but becomes fixed from this formula (25) and formula (23). In this case, the temperature coefficient and positive/negative of resistance R1 become reverse, and the temperature coefficient of Io is delta Io/delta T/Io=+1000ppm/degree C. (26)

It becomes. Although this is the temperature coefficient of the output current when carrying out the assumption of a formula (23) and (24), this assumption is not realized in practice.

[0045] An actual numeric value is as follows. That is, there is no temperature dependence, namely, the output current Io is delta Io/delta T= 0. (27)

It comes out. For this reason, it will depend for the rate of a temperature change of VBE1 only on the temperature characteristic (temperature coefficient) of the saturation current Is from a formula (21). When the rate of a temperature change of VBE2 at the time of taking into consideration the temperature coefficient of the saturation current Is and the temperature coefficient of Current Iref like a formula (17) from this formula (27) and formula (20) is set to deltaVBE2"/deltaT, it is (deltaVBE2"/delta T-delta VBE1/delta T)/(VBE2-VBE1).

= deltaR1/delta T/R1 (28)

It becomes possible by materializing ******** and this relational expression to reduce the temperature coefficient of the output current Io.

[0046] From a formula (28), the value of VBE1, Io, and R1 which fulfill the conditions of output current delta Io/delta T= 0 in T=300K and Iref=100microA is calculated as an example. That is, the formula same also to VBE1 as a formula (12) is realized by the formula (21), and it is deltaVBE1/deltaT=1/T [-Eg+VBE1- (4-a) and kT/q].

It is expressed. This is substituted for a formula (28). In addition, it is set to Eg+ (4-a) and kT/q=1252mV with the already described value. Moreover, since a formula (17) is realized also here, it is deltaVBE2"/deltaT=-1.58+ (-0.026).

= It is -1.606mV/degree C. Moreover, it is /R1=-1000ppm/degree C as mentioned above (delta R1/delta T). Moreover, since a formula (11) is realized also here, it is VBE2=Vt-ln(Iref/Is) =778mV by Iref=100microA. Consequently, from a formula (28), it is set to 1= 772mV of VBE(s), and is set to Io=79.2microA from Vt=kT/q=26mV and log(Is) =-17 by the formula (21). Therefore, the resistance R1 for temperature compensation at this time is set to R1=(778-772) mV /

79.2micro A= 75.8 ohms.
[0047] Then, what is necessary is just to choose as the above R1 at least an ingredient which has a temperature coefficient (temperature dependence) with which the above-mentioned formula (28) is filled in VBE1 and Io of the temperature acquired for the time of use which fill the above-mentioned formula (21) in all those temperature, and VBE1, VBE2, Io and R1 which fill the above-mentioned formula (20) preferably in part. By doing in this way, the temperature dependence of the output current Io can be remarkably decreased in the temperature.
[0048] The electrical potential difference which joins VBE1 and the resistance R1 for temperature compensation has an exponential relation here so that the above-mentioned numeric value may show, and as for the resistance R1 for temperature compensation, in the above-mentioned case, it is desirable to consider as a very small value compared with Rs. On process variation, since the minimum resistance is about 1kohm, as for the resistance R1 for temperature compensation, it is desirable to consider as the configuration which consists of parallel connection of resistance of several. Moreover, since the constant current generating circuit concerning the gestalt of this above-mentioned implementation is performing temperature compensation according to the difference of Iref and Io, the adjustment of Rs and R1 is important for it. For this reason, when process variation control of Rs and R1 resistance is taken into consideration, as for Rs and R1, it is desirable to carry out contiguity arrangement and to consist of resistance of the same configuration. Therefore, in Rs=7.78kohm, R1 becomes 100 parallel connection of the same form drag as Rs.
[0049] On the other hand, in the constant current generating circuit shown in drawing 2 , in the configuration of drawing 1 , while having the resistance R1 for temperature compensations as 1st component for temperature compensations between the emitter of the transistor Tr1 for an output, and GND, it has the resistance R2 for temperature compensations as 2nd component for temperature compensations between the emitter of the transistor Tr2 for electrical-potential-difference criteria, and GND. When the electrical potential difference between the both ends of the resistance R2 for temperature compensation of this constant current generating circuit is set to VR2, the electrical potential difference VB between Current Iref and Points B and GND is Iref=VBE2/(Rs-R2). (29)
VR2=Iref-R2 (30)
More, it is VB=VBE2+VR2=VBE2- (31). [1+R2/(Rs-R2)]
A next door and the rate of a temperature change of VB are delta VB/delta T=delta VBE2/delta T. (32)
It becomes. Therefore, the case of the constant current generating circuit of drawing 2 , and as well as the time of the constant current generating circuit of drawing 1 when the temperature coefficient of an electrical potential difference VB adds the resistance R2 for temperature compensation like the constant current generating circuit of drawing 1 only depending on the temperature coefficient of VBE2, the temperature coefficient of the output current Io is calculated. Therefore, by adding the resistance R2 for temperature compensation, it becomes possible to enlarge the electrical potential difference which joins the resistance R1 for temperature compensation as compared with the case of the constant current generating circuit of drawing 1 , and, for this reason, the resistance of R1 can be greatly set up now. Therefore, it becomes possible to set the resistance R1 for temperature compensation as Rs and a near value, and to control temperature dependence of the output current Io by having the configuration of the constant current generating circuit of drawing 2 . That is, since Rs and R1 can be made into a near value as much as possible, it is effective especially from a viewpoint of layout reductions of area.
[0050] In addition, in the constant current generating circuit where the base of the transistor Tr1 for an output and the transistor Tr2 for electrical-potential-difference criteria was connected, and the mutual emitter was connected to GND, and the resistance Rs which has a negative temperature coefficient between emitters was connected with the base of said transistors Tr1 and Tr2, the constant current generating circuit concerning this invention may be constituted so that it may have a component for temperature compensation between the emitter of said transistor, and GND.

[0051] Moreover, in the above-mentioned configuration, the constant current generating circuit concerning this invention may be constituted so that the component for temperature compensation may be prepared between the emitter of the transistor Tr1 for an output, and GND.
[0052] According to the above-mentioned configuration, the change to the output current temperature of a constant current generating circuit can be controlled by adding and providing the component for temperature compensation between the emitter of the transistor Tr1 for an output, and GND. the high-speed process in which, as for the current generating circuit on the basis of such a VBE electrical potential difference, resistance has the temperature coefficient of minus for improvement in the speed of a light-receiving amplifying circuit -- it is, and it is having a component for temperature compensation between the emitter of the transistor Tr1 for an output, and GND, and control of the change to the temperature of the output current is attained.

[0053] Moreover, in the above-mentioned configuration, the constant current generating circuit concerning this invention may be constituted so that the 1st component for temperature compensations may be prepared between the emitter of said transistor Tr1 for an output, and GND and the 2nd component for temperature compensations may be prepared between the emitter of the transistor Tr2 for electrical-potential-difference criteria, and GND. According to the above-mentioned configuration, the higher temperature-compensation effectiveness can be acquired. By having such an emitter of the transistor Tr2 for electrical-potential-difference criteria, and a component for temperature compensation between GND, it becomes possible to make R1 into the resistance of Resistance Rs and near, and the control to the temperature of the output current of the constant current generating circuit stabilized more can be obtained.
[0054] Moreover, in the above-mentioned configuration, the constant current generating circuit concerning this invention may be constituted so that said component for temperature compensation may consist of resistance.
[0055] Moreover, in the above-mentioned configuration, the constant current generating circuit concerning this invention may come to carry out parallel connection of two or more resistance of the same configuration as Resistance Rs, and it may constitute the resistance which is said component for temperature compensation as Resistance Rs is adjoined and it is arranged.
[0056]
[Effect of the Invention] As mentioned above, the constant current generating circuit of this invention is the configuration that the 1st component for temperature compensation was prepared between the emitter of the transistor for an output, and GND.
[0057] Each other is mutually offset by this by the temperature dependence of the electrical potential difference between base-emitters of each transistor, and the temperature dependence of the 1st component for temperature compensation, and temperature dependence of the output current can be made small as a whole. So, the effectiveness that the temperature dependence of the output current can be decreased effectively is done.
[0058] Moreover, the constant current generating circuit of this invention is a configuration which add to the above-mentioned configuration, and the component for temperature compensation of the above 1st comes to carry out parallel connection of two or more resistance of the same configuration as the above-mentioned resistance Rs, and adjoins the above-mentioned resistance Rs, and is arranged.
[0059] Thereby, formation of the component for temperature compensation of the above 1st is possible in the same manufacture process as Resistance Rs. So, in addition to the effectiveness by the above-mentioned configuration, the effectiveness that it can be an easy configuration, and can be accurate, and the temperature dependence of the output current Io can be reduced is done.
[0060] Moreover, the constant current generating circuit of this invention is the configuration that the 2nd component for temperature compensation was prepared between the emitter of the above-mentioned transistor for electrical-potential-difference criteria, and GND in addition to the above-mentioned configuration.
[0061] Thereby, ****** of a sufficiently big value can be applied to the component for

temperature compensation of the above 1st by having the 2nd component for temperature compensation. So, even if it adopts a component with big resistance as a component for temperature compensation of the above 1st, it stops interfering in addition to the effectiveness by the above-mentioned configuration, and the effectiveness that the degree of freedom of an ingredient and the degree of freedom of designs (arrangement of a component etc.) can be extended is done.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the circuit diagram showing the example of 1 configuration of the constant current generating circuit concerning this invention.
[Drawing 2] It is the circuit diagram showing other examples of a configuration of the constant current generating circuit concerning this invention.
[Drawing 3] It is the circuit diagram showing the example of a configuration of the light-receiving amplifying circuit for pickup.
[Drawing 4] It is the circuit diagram showing the example of a configuration of the conventional constant current generating circuit.
[Drawing 5] It is the circuit diagram showing the example of a configuration of the conventional constant current generating circuit.
[Drawing 6] It is the graph which shows the gain-response frequency characteristics of the light-receiving amplifying circuit for pickup.
[Description of Notations]
11 Active Load
R1 Resistance for temperature compensation (1st component for temperature compensation)
R2 Resistance for temperature compensation (2nd component for temperature compensation)
Tr1 Transistor for an output
Tr2 Transistor for electrical-potential-difference criteria

[Translation done.]

* NOTICES *

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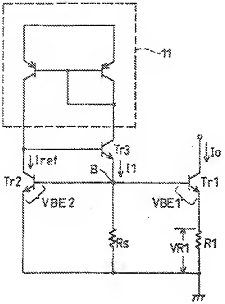
damages caused by the use of this translation.

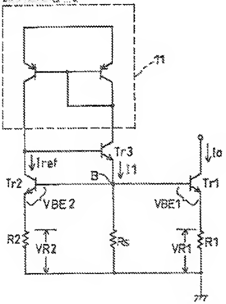
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

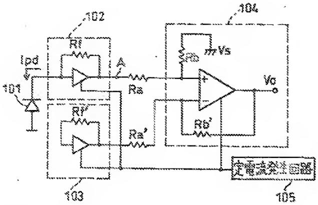
[Drawing 1]



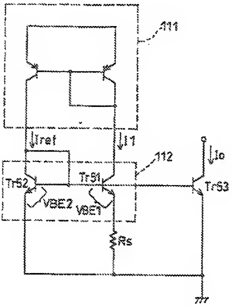
[Drawing 2]



[Drawing 3]



[Drawing 4]



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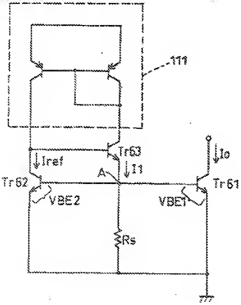
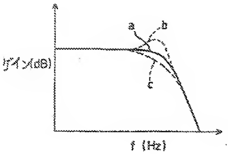


[Drawing 6]



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(71)出願人　000005049
シャープ株式会社
大阪府大阪市阿倍野区長池町22番22号

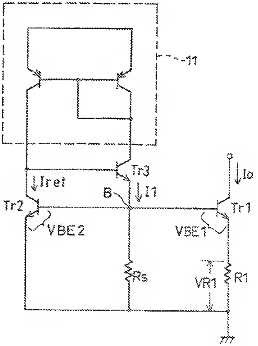
(72)発明者　大西　雅也
大阪府大阪市阿倍野区長池町22番22号　シャープ株式会社内

(74)代理人　100080034
弁理士　原　謙三

最終頁に続く

(54)【発明の名称】　定電流発生回路

(57)【要約】
【課題】　定電流発生回路において、出力電流の温度依存性を効果的に減少させる。
【解決手段】　出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベースが接続され、かつ互いのエミッタがＧＮＤに接続され、上記出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベースとエミッタ間に抵抗Ｒｓが接続されている。出力用トランジスタＴｒ１のエミッタとＧＮＤ間に第１の温度補償用素子としての温度補償用抵抗Ｒ１を設ける。



【特許請求の範囲】

【請求項１】出力用トランジスタと電圧基準用トランジスタのベースが互いに接続され、上記両トランジスタの各エミッタがＧＮＤに接続され、上記出力用トランジスタと電圧基準用トランジスタのベースとエミッタとの間に抵抗Ｒｓが接続された定電流発生回路において、
上記出力用トランジスタのエミッタとＧＮＤとの間に第１の温度補償用素子が設けられたことを特徴とする定電流発生回路。

【請求項２】上記第１の温度補償用素子が、上記抵抗Ｒｓと同一形状の複数の抵抗を並列接続してなり、かつ上記抵抗Ｒｓと隣接して配置されていることを特徴とする請求項１記載の定電流発生回路。

【請求項３】上記電圧基準用トランジスタのエミッタとＧＮＤとの間に第２の温度補償用素子が設けられたことを特徴とする請求項１または２記載の定電流発生回路。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ＤＶＤ、ＣＤ－ＲＯＭ、ＣＤ－Ｒ、ＣＤ－ＲＷ用ピックアップシステムなどの受光増幅素子等に用いられる定電流発生回路に関するものである。

【０００２】

【従来の技術】ＤＶＤ、ＣＤ－ＲＯＭ、ＣＤ－Ｒ、ＣＤ－ＲＷ用ピックアップシステムなどには受光増幅素子が用いられている。この中でも現在のＤＶＤ－ＲＯＭ市場＊は、１０倍速ＤＶＤ－ＲＯＭピックアップシステムが主流であり、数社のピックアップメーカーは、１６倍速ＤＶＤ－ＲＯＭの開発を進めている。今後、特にＤＶＤ市場は、さらに高速化の方向に進むと予想される。このため、ピックアップ用受光増幅回路の一層の高速化が必要となる。

【０００３】図３にピックアップ用受光増幅回路のブロック図を示す。ここに示すピックアップ用受光増幅回路は、信号光を受光するフォトダイオード１０１とフォトダイオード１０１に接続された電流電圧変換回路１０２、リファレンス回路１０３、電流電圧変換回路１０２により変換された電圧信号をさらに増幅する差動回路１０４および前記回路を全てバイアスする定電流発生回路１０５から構成されている。

【０００４】図３のピックアップ用受光増幅回路の動作原理を説明すると以下のようになる。

【０００５】ＣＤまたはＤＶＤディスクの反射信号光がフォトダイオード１０１に入力し発生した信号電流Ｉｐｄは、電流電圧変換回路１０２のフィードバック抵抗Ｒｆにより電圧変換され、図３の矢印で示す方向に信号電流Ｉｐｄが流れる場合、電流電圧変換回路１０２の出力電位点Ａは上昇し、さらに後段の差動回路１０４により非反転増幅され出力電圧Ｖｏが生じる。ここでＶｓは、外部から供給される規定電圧であり、信号電流Ｉｐｄが生じた時の電圧変換式は以下のように表される。

$$V_o = R_f \cdot R_b / R_a \cdot I_{pd} \qquad (1)$$

また、図３のブロック図に示すように、定電流発生回路１０５は、全ての増幅回路のバイアス電流を供給しており、周囲温度の変化により定電流発生回路１０５の出力電流が変化した場合、図６に示すように、ピックアップ用受光増幅回路の特性変動が生じる。図中、曲線ａ、ｂ、ｃはそれぞれ、定電流発生回路の出力電流が正常の場合、正常時より大きい場合、正常時より小さい場合である。このため、定電流発生回路の出力電流は、周囲温度に限りなく依存しないように設計する必要がある。

【０００６】前述したようにピックアップ用受光増幅回路は高速化が進んでおり、そのための高集積高速プロセスの開発が行われている。高速プロセスにおいて重要な要素は、トランジスタ、抵抗などの素子に付随する寄生容量の低減である。

【０００７】次に、抵抗素子に付随する寄生容量を低減したプロセスにおける定電流発生回路の出力電流の温度に対する安定化について述べる。

【０００８】従来プロセスでの従来型の定電流発生回路の一例を図４に示す。この構成では、トランジスタＴｒ５１、Ｔｒ５２、Ｔｒ５３が設けられている。従来プロセスの場合、主要な抵抗は、Ｐ型単結晶半導体で形成されており、Ｐ型単結晶半導体抵抗の温度係数およびシート抵抗値（Ω／□）（□は導体の幾何学的な四角形（単位面積）を表す）は不純物であるボロンの注入量よって決定されている。また、この半導体抵抗は、プラスの温度係数を有し、ボロンの注入量を多くした場合、つまりシート抵抗値を小さくした場合の抵抗の温度係数は低下し、逆にボロンの注入量を少なくした場合、シート抵抗値は大きくなり、温度係数も大きくなる。このプラスの温度係数は、温度上昇により半導体内の分子運動が活性化し、キャリアつまり注入されたボロンの移動が抑制されることによる。実際の回路設計上では、シート抵抗値を下げ温度係数の低い抵抗を使用することも可能であるが、低いシート抵抗で抵抗値の大きい抵抗を得るためには、チップ内の抵抗素子の形状を極端に長くする必要が生じる。また、このような半導体抵抗の場合、抵抗のＰ型半導体とＮ型エピタキシャル層の間にＰＮ接合により形成される空乏層による寄生容量が付随し、抵抗素子の形状を大きくすることは回路高速化の上でマイナス要素である。

【０００９】上記内容を考慮し、従来プロセスでは、＋３０００ｐｐｍ／℃前後の温度係数を有する抵抗を使用している。ここで、抵抗の温度係数を＋３０００ｐｐｍ／℃とし、以下に従来型の定電流発生回路の出力電流の温度に対する安定性を得る方法を説明する。図４に示す、従来プロセスでの従来技術の定電流発生回路では、

領域１１２において熱電圧（Ｖｔ）温度係数＋３３００ｐｐｍ／℃により温度補償を行っており、この場合の出力電流Ｉｏと出力電流の温度係数は

$$VBE2=VBE1+Rs\cdot I1 \qquad (2)$$

$$Vt\cdot \ln(Iref/Is)=Vt\cdot \ln\{I1/(10\cdot Is)\}+Rs\cdot I1 \qquad (3)$$

Ｉｒｅｆ＝Ｉ１＝Ｉｏなので

$$Io=Vt\cdot \ln 10/Rs \qquad (4)$$

ここで、Ｖｔ＝（ｋ×Ｔ）／ｑ

ｋ：ボルツマン定数

ｑ：電子の電荷量

Ｔ：絶対温度

Ｉｓ：ＰＮ接合の飽和電流

である。なお、「Δ」は微分を表す。

【００１０】出力電流Ｉｏの温度係数１／Ｉｏ・ΔＩｏ／ΔＴは式（４）より

$$\Delta Io/\Delta T=\Delta(Vt\cdot \ln 10/Rs)/\Delta T \qquad (5)$$

$$=Vt\cdot \ln 10/Rs\cdot\{1/Vt\cdot(\Delta Vt/\Delta T)-1/Rs\cdot(\Delta Rs/\Delta T)\} \qquad (6)$$

$$=Io\cdot\{1/Vt\cdot(\Delta Vt/\Delta T)-1/Rs\cdot(\Delta Rs/\Delta T)\} \qquad (7)$$

よって

$$1/Io\cdot\Delta Io/\Delta T=1/Vt\cdot(\Delta Vt/\Delta T)-1/Rs\cdot(\Delta Rs/\Delta T) \qquad (8)$$

となる。

【００１１】熱電圧（Ｖｔ）温度係数＋３３００ｐｐｍ／℃と抵抗の温度係数＋３０００ｐｐｍ／℃が相殺され、

$$\text{出力電流}Io\text{の温度係数}=+3300ppm/℃-(+3000ppm/℃)=+300ppm/℃ \qquad (9)$$

となる。ここで、図４の能動負荷１１１は、Ｉ１＝Ｉｏを得るための回路であり、これ以降に示す定電流発生回路における能動負荷も同様の役割を果たす。

【００１２】前述したように、増幅回路の高速化のためには、半導体抵抗に付随する寄生容量の低減が重要であり、寄生容量低減を目的とした高速プロセス開発において、半導体抵抗の温度係数がマイナスになる場合が生じている。これは、Ｐ型半導体抵抗を多結晶シリコンで形成しているためである。

【００１３】多結晶シリコンは、Ｐ型単結晶シリコンと比べて結晶粒が小さいため、Ｎ型エピタキシャル層との間に極端なＰＮ接合が形成されず、寄生容量が付随しない。また、Ｐ型多結晶シリコン半導体抵抗においても、Ｐ型単結晶シリコンの場合と同様にシート抵抗値および温度係数をボロンの注入量により変えることが可能であるが、Ｐ型多結晶半導体シリコン抵抗の温度係数は、結晶粒内つまり単結晶部よりも結晶粒界の挙動が支配的となり、マイナスの温度係数を有する。

【００１４】ここでは、温度変化に対する出力電流の変化を抑制した定電流発生回路では、高速プロセスでのＰ型多結晶シリコン半導体抵抗の温度係数を－１０００ｐｐｍ／℃として考察する。ここで抵抗の温度係数がマイナスの場合の従来型定電流発生回路の例を図５に示す。この構成では、トランジスタＴｒ６１、Ｔｒ６２、Ｔｒ６３が設けられている。

【００１５】この回路は、ベース－エミッタ間電圧ＶＢＥを基準電圧に用いた定電流発生回路であり、この回路の出力電流ＩｏはトランジスタＴｒ６２のＶＢＥ２と抵抗Ｒｓにより以下のように決定される。なお、ｌｏｇは常用対数である。

$$Io\approx VBE2/Rs \qquad (10)$$

ここで、ＶＢＥ２は、

$$VBE2=Vt\cdot \ln(Iref/Is) \qquad (11)$$

であり、

Ｉｒｅｆ＝１００μＡ

Ｒｓ＝７．７８ｋΩ

ｌｏｇ（Ｉｓ）＝－１７

シリコンのエネルギーギャップ　Ｅｇ＝１．２Ｖ

定数　（４－ａ）＝２

Ｔ＝３００Ｋ

Ｖｔ＝ｋＴ／ｑ＝２６ｍＶ

とした場合（以下特記無い場合の数値計算は上記数値で行う）、

ＶＢＥ２＝Ｖｔ・ｌｎ（Ｉｒｅｆ／Ｉｓ）＝７７８ｍＶ

となる。

【００１６】まず、ΔＩｒｅｆ／ΔＴ＝０と仮定し、飽和電流Ｉｓの温度特性（ΔＩｓ／ΔＴ）のみ考慮すると

$$\Delta VBE2/\Delta T=1/T\{-Eg+VBE2-(4-a)\cdot kT/q\}=-1.58mV/℃ \qquad (12)$$

よって

$$(\Delta VBE2/\Delta T)/VBE2=-1.58\ (mV/℃)/778\ (mV) =-2031\ ppm/℃ \qquad (13)$$

になり、点Aの電位は−2031ppm/℃の温度係数で低下する。

【0017】Ioの温度係数は式(10)より

$$\Delta Io/\Delta T=1/Rs\cdot\Delta VBE2/\Delta T -VBE2/(Rs\cdot Rs)\cdot\Delta Rs/\Delta T \qquad (14)$$

であり、抵抗値Rsの温度係数(ΔRs/ΔT)/Rsが上記のように(ΔRs/ΔT)/Rs=−1000ppm/℃である。したがって

$$(\Delta Io/\Delta T)/Io=(\Delta VBE2/\Delta T)/VBE2-(\Delta Rs/\Delta T)/Rs =-2031-(-1000)=-1031\ ppm/℃ \qquad (15)$$

となる。

【0018】さらに、式(13)では、便宜的に電流Irefの温度係数ΔIref/ΔT=0として計算しているが、実際の電流Irefは−1031ppm/℃の温度係数を有しており、VBE2の温度係数は−1.58mV/℃より大きい。すなわち、温度T=固定、Is=固定(ΔIs/ΔT=0)の時の電流Irefの変動によるVBE2の温度変化率は

$$\Delta VBE2/\Delta T=-0.026\ mV/℃ \qquad (16)$$

(ΔIref/ΔT=−1031ppm/℃、ΔIs/ΔT=0のとき)である。

【0019】これにより、電流Irefの温度係数と総和電流Isの温度係数とを考慮した時(' を付す)のVBE2の温度変化率は

$$\Delta VBE2'/\Delta T=-1.58+(-0.026) =-1.606\ mV/℃ \qquad (17)$$

となり、したがってこのときのVBE2の温度係数は(ΔVBE2'/ΔT)/VBE2'=−1.606/778=−2064ppm/℃となる。したがってこのときのIoの温度係数は(ΔIo'/ΔT)/Io'=−2064−(−1000)=−1064ppm/℃となる。

【0020】よって、図5に示す従来型の定電流発生回路において抵抗Rsの温度係数が−1000ppm/℃の場合、出力電流Ioの温度係数は、その絶対値において、図4に示す従来プロセスでの従来回路の温度係数+300ppm/℃と比較しても大きく、この定電流発生回路方式では、温度変化に対する出力電流Ioの変化を抑制することは困難である。

【0021】

【発明が解決しようとする課題】定電流発生回路出力電流の温度に対する変化が大きい場合、温度変化に対するピックアップ用受光増幅回路の特性の安定性が得られ難くなる。例えば、前述した図5に示す従来型の定電流発生回路において、ピックアップ用受光増幅回路の動作温度範囲−10℃~+85℃のなかで、25℃から35℃への周囲温度変動を考えた場合、出力電流、つまりピックアップ用受光増幅回路のバイアス電流Iccの変化は、

$$-1064\ ppm/℃\times(85-25)℃/1000000 =-0.064 \qquad (18)$$

であり、上記温度変化により増幅回路のバイアス電流は6.4%減少することになる。

【0022】この変動により、ピックアップ用受光増幅回路の主要特性であるゲイン−応答周波数特性や外部電源Vsと出力電圧Voの差であるオフセット電圧などが悪化する。ピックアップ用受光増幅回路の応答周波数特性波形は前述の図6に示した通りである。バイアス電流が増加した場合、増幅回路のオープンループゲイン増加により位相余裕が減少し、ゲインピーキングが生じる。これとは逆にバイアス電流が低下した場合は、応答周波数の帯域が狭くなり、信号伝達可能周波数が低下する問題がある。このため、定電流発生回路の出力電流の温度依存は極力抑制する必要がある。定電流発生回路の出力電流の温度係数は、0ppm/℃が理想的である。

【0023】本発明は、上記問題点に鑑みなされたものであり、その目的は、出力電流の温度依存性を効果的に減少させることができる定電流発生回路を提供することにある。

【0024】

【課題を解決するための手段】上記の課題を解決するため、本発明の定電流発生回路は、出力用トランジスタと電圧基準用トランジスタのベースが互いに接続され、上記両トランジスタの各エミッタがGNDに接続され、上記出力用トランジスタと電圧基準用トランジスタのベースとエミッタとの間に抵抗Rsが接続された定電流発生回路において、上記出力用トランジスタのエミッタとGNDとの間に第1の温度補償用素子が設けられたことを特徴としている。

【００２５】上記の構成により、出力用トランジスタのエミッタとＧＮＤとの間に第１の温度補償用素子が設けられている。

【００２６】したがって、出力用トランジスタのバイアス電流すなわち出力電流と、電圧基準用トランジスタのバイアス電流とが互いに異なる値になる。その結果、出力用トランジスタのベース－エミッタ間電圧（ＶＢＥ１）と電圧基準用トランジスタのベース－エミッタ間電圧（ＶＢＥ２）とが互いに異なる温度係数（温度依存性）を有するようになる。そして、各トランジスタのベース－エミッタ間電圧の温度依存性と第１の温度補償用素子の温度依存性とで互いに相殺され、全体として出力電流の温度依存性を小さくすることができる。

【００２７】それゆえ、出力電流の温度依存性を効果的に減少させることができる。なお、上記抵抗Ｒｓが負の温度係数を有する場合に、従来と比べて、より著しく、出力電流の温度依存性を減少させることができる。すなわち、本発明により、上記ピックアップ用受光増幅回路における定電流発生回路出力電流の周囲温度変化に対する安定化を行うことができる。

【００２８】また、本発明の定電流発生回路は、上記の構成に加えて、上記第１の温度補償用素子が、上記抵抗Ｒｓと同一形状の複数の抵抗を並列接続してなり、かつ上記抵抗Ｒｓと隣接して配置されていることを特徴としている。

【００２９】上記の構成により、上記第１の温度補償用素子が、上記抵抗Ｒｓと同一形状の複数の抵抗を並列接続してなり、かつ、上記抵抗Ｒｓと隣接して配置されている。

【００３０】したがって、上記第１の温度補償用素子の抵抗値として小さい値が望まれる場合に、単体でそのような小さい抵抗値を持つ必要がない。そのため、汎用な抵抗素子等を上記第１の温度補償用素子として用いることができる。また、上記第１の温度補償用素子が、上記抵抗Ｒｓと同一形状の素子であるため、抵抗Ｒｓと同じ製造プロセスで上記第１の温度補償用素子の形成が可能である。

【００３１】それゆえ、上記の構成による効果に加えて、簡単な構成で、かつ、精度よく、出力電流Ｉｏの温度依存性を低減させることができる。

【００３２】また、本発明の定電流発生回路は、上記の構成に加えて、上記電圧基準用トランジスタのエミッタとＧＮＤとの間に第２の温度補償用素子が設けられたことを特徴としている。

【００３３】上記の構成により、上記電圧基準用トランジスタのエミッタとＧＮＤ間に第２の温度補償用素子が設けられている。したがって、第２の温度補償用素子を備えることにより、上記第１の温度補償用素子に、十分大きな値の電圧を加えることができる。

【００３４】それゆえ、上記の構成による効果に加えて、上記第１の温度補償用素子として、抵抗値の大きな素子を採用しても差し支えなくなり、材料の自由度や設計（素子の配置等）の自由度を広げることができる。

【００３５】

【発明の実施の形態】本発明の実施の一形態について図１および図２に基づいて説明すれば、以下の通りである。

【００３６】図１は、本実施の形態に係る第１の温度補償用素子としての温度補償用抵抗Ｒ１を有する定電流発生回路の一例である。

【００３７】出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベース同士が接続され、かつ互いのエミッタがＧＮＤに接続されている。また、出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベースとエミッタ間に、負の温度係数を有する抵抗Ｒｓが接続されている。そして、出力用トランジスタＴｒ１のエミッタとＧＮＤ間に、第１の温度補償用素子として温度補償用抵抗Ｒ１が設けられている。Ａ点は、出力用トランジスタＴｒ１のエミッタと温度補償用抵抗Ｒ１との接続点である。Ｂ点は、出力用トランジスタＴｒ１のベース、電圧基準用トランジスタＴｒ２のベース、および抵抗Ｒｓの接続点である。出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２とにおいては、そのエミッタ面積比は１である。また、トランジスタＴｒ３が設けられている。

【００３８】能動負荷１１は、前述したように、図４同様、Ｉ１＝Ｉｏを得るための回路である。これの２つの端子がトランジスタＴｒ３のコレクタとベースに接続され、このトランジスタＴｒ３のベースは、上記電圧基準用トランジスタＴｒ２のコレクタに接続されている。トランジスタＴｒ３のエミッタは、出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベースに接続されている（Ｂ点とする）。

【００３９】ここでは、図５の構成同様、温度補償用抵抗Ｒ１はＰ型多結晶シリコン半導体抵抗を用いて作製されており、温度係数（ΔＲ１／ΔＴ）／Ｒ１が

（ΔＲ１／ΔＴ）／Ｒ１＝－１０００ｐｐｍ／℃

となっている。

【００４０】前述した図５に示す従来型の定電流発生回路の数値例の場合には、温度補償用抵抗Ｒ１を有していないＶＢＥを基準とした定電流発生回路の出力電流Ｉｏは－１０６４ｐｐｍ／℃の温度係数を持つ。

【００４１】一方、本実施の形態では、上記のように、出力用トランジスタＴｒ１のエミッタとＧＮＤ間に第１の温度補償用素子としての温度補償用抵抗Ｒ１を有している。そして、このように第１の温度補償用素子を温度補償用抵抗（Ｒ１）とする場合、この温度補償用抵抗Ｒ１の抵抗値を変えることにより、出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のバイアス電流値ＩｏとＩｒｅｆとを異なる値に設定し、それぞれ出力用

トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のＶＢＥ１、ＶＢＥ２の温度係数を変えることで出力電流Ｉｏの温度変化を抑制することが可能である。

【００４２】図１の定電流発生回路の電流Ｉｒｅｆ、Ｉｏは、それぞれ

$$Iref = VBE2 / Rs \qquad (19)$$

$$Io = (VBE2 - VBE1) / R1 \qquad (20)$$

であり、また、

$$VBE1 = Vt \cdot \ln(Io / Is) \qquad (21)$$

である。

【００４３】前述したように、本実施の形態では、温度補償用抵抗Ｒ１によりＩｒｅｆ≠Ｉｏにすることが可能になる。ＩｒｅｆとＩｏとがＩｒｅｆ≠Ｉｏの関係を有する時、ＶＢＥ２、ＶＢＥ１の温度係数は、式（１１）、（１２）、（２１）より

$$\Delta VBE2 / \Delta T / VBE2 \neq \Delta VBE1 / \Delta T / VBE1 \qquad (22)$$

となる。なお、記号「Δ」は微分を表す。つまり、ＩｒｅｆとＩｏの電流値に差を付けることで、温度変化が生じた場合のトランジスタベース－エミッタ間電圧ＶＢＥ１、ＶＢＥ２の温度係数に差を付けることが可能となる。図１の定電流発生回路では、この調整可能なＶＢＥ１、ＶＢＥ２の温度係数差を利用して、出力電流Ｉｏの温度係数変化の抑制を行う。

【００４４】まず、基本的な動作説明のため、

$$\Delta VBE2 / \Delta T / VBE2 = \Delta VBE1 / \Delta T / VBE1 \qquad (23)$$

$$\Delta Iref / \Delta VBE2 = \Delta Io / \Delta VBE1 = 0 \qquad (24)$$

と仮定した場合、図１の定電流発生回路の点ＡとＧＮＤとの間の電圧ＶＲ１は次の式

$$VR1 = VBE2 - VBE1 \qquad (25)$$

で表され、この式（２５）と式（２３）より、ＶＲ１は温度によらず一定となる。この場合Ｉｏの温度係数は、抵抗Ｒ１の温度係数と正負が逆になり、

$$\Delta Io / \Delta T / Io = +1000\,ppm/℃ \qquad (26)$$

となる。これは式（２３）、（２４）の仮定をした時の出力電流の温度係数であるが、実際は、この仮定は成り立たない。

【００４５】実際の数値は以下のようになる。すなわち、出力電流Ｉｏは温度依存が無い、すなわち

$$\Delta Io / \Delta T = 0 \qquad (27)$$

である。このため、式（２１）より、ＶＢＥ１の温度変化率は飽和電流Ｉｓの温度特性（温度係数）だけに依存することになる。この式（２７）と式（２０）とより、式（１７）のように飽和電流Ｉｓの温度係数と電流Ｉｒｅｆの温度係数とを考慮した場合のＶＢＥ２の温度変化率をΔＶＢＥ２″／ΔＴとすると、

$$(\Delta VBE2'' / \Delta T - \Delta VBE1 / \Delta T) / (VBE2 - VBE1) = (\Delta R1 / \Delta T) / R1 \qquad (28)$$

が得られ、この関係式を成り立たせることにより、出力電流Ｉｏの温度係数を低減することが可能となる。

【００４６】式（２８）より、例として、Ｔ＝３００Ｋ、Ｉｒｅｆ＝１００μＡでの、出力電流ΔＩｏ／ΔＴ＝０の条件を満たすＶＢＥ１、ＩｏおよびＲ１の値を求める。すなわち、式（２１）によりＶＢＥ１にも式（１２）と同様の式が成り立って

$$\Delta VBE1 / \Delta T = 1/T \{-Eg + VBE1 - (4-a) \cdot kT/q\}$$

と表される。これを式（２８）に代入する。なお、すでに述べた値により

$$Eg + (4-a) \cdot kT/q = 1252\,mV$$

となる。また、ここでも式（１７）が成り立つので

$$\Delta VBE2'' / \Delta T = -1.58 + (-0.026) = -1.606\,mV/℃$$

である。また、上述のように

$$(\Delta R1 / \Delta T) / R1 = -1000\,ppm/℃$$

である。また、ここでも式（１１）が成り立つので、Ｉｒｅｆ＝１００μＡにより

$$VBE2 = Vt \cdot \ln(Iref / Is) = 778\,mV$$

である。この結果、式（２８）より、

$$VBE1 = 772\,mV$$

となり、式（２１）で

$$Vt = kT/q = 26\,mV,\ \log(Is) = -17$$

より

$$Io = 79.2\,\mu A$$

となる。そのため、このときの温度補償用抵抗Ｒ１は、

$$R1 = (778 - 772)\,mV / 79.2\,\mu A = 75.8\,\Omega$$

となる。

【００４７】そこで、使用時にとりうる温度の少なくとも一部、好ましくはそのすべての温度において、上記式（２１）を満たすＶＢＥ１とＩｏ、上記式（２０）を満たすＶＢＥ１、ＶＢＥ２、Ｉｏ、Ｒ１において、上記式（２８）が満たされるような温度係数（温度依存性）を有するような材料を上記Ｒ１に選べばよい。このようにすることで、その温度において、出力電流Ｉｏの温度依存性を著しく減少させることができる。

【００４８】ここで、上記数値から分かるようにＶＢＥ１と温度補償用抵抗Ｒ１に加わる電圧は、指数関数的な関係にあり、上記の場合、温度補償用抵抗Ｒ１はＲｓに比べ極めて小さい値とすることが好ましい。プロセスバラツキ上、最小抵抗値は、１ｋΩ程度であることから、温度補償用抵抗Ｒ１は、数本の抵抗の並列接続からなる構成とすることが好ましい。また、上記本実施の形態に係る定電流発生回路は、ＩｒｅｆとＩｏの差により温度補償を行っているため、ＲｓとＲ１の整合性が重要である。このため、Ｒｓ，Ｒ１抵抗のプロセスバラツキ抑制を考慮した場合，ＲｓとＲ１は、隣接配置し、同一形状の抵抗からなることが好ましい。したがって、Ｒｓ＝７．７８ｋΩの場合、Ｒ１はＲｓと同一形状抵抗の並列接続１００個となる。

【００４９】一方、図２に示す定電流発生回路においては、図１の構成において、出力用トランジスタＴｒ１のエミッタとＧＮＤとの間に第１の温度補償用素子としての温度補償用抵抗Ｒ１を有するとともに、電圧基準用トランジスタＴｒ２のエミッタとＧＮＤとの間に第２の温度補償用素子としての温度補償用抵抗Ｒ２を有している。この定電流発生回路の温度補償用抵抗Ｒ２の両端間の電圧をＶＲ２とした時、電流Ｉｒｅｆと、点ＢとＧＮＤとの間の電圧ＶＢは、

$$Iref = VBE2/(Rs-R2) \quad (29)$$

$$VR2 = Iref \cdot R2 \quad (30)$$

より、

$$VB = VBE2 + VR2$$

$$= VBE2 \cdot \{1 + R2/(Rs-R2)\} \quad (31)$$

となり，ＶＢの温度変化率は

$$\Delta VB/\Delta T = \Delta VBE2/\Delta T \quad (32)$$

となる。したがって，図２の定電流発生回路の場合も、図１の定電流発生回路と同様に、電圧ＶＢの温度係数はＶＢＥ２の温度係数のみに依存し、温度補償用抵抗Ｒ２を付加した場合も、図１の定電流発生回路の時と同様に、出力電流Ｉｏの温度係数が計算される。したがって、温度補償用抵抗Ｒ２を付加することで，図１の定電流発生回路の場合と比較して，温度補償用抵抗Ｒ１に加わる電圧を大きくすることが可能となり，このためＲ１の抵抗値を大きく設定することができるようになる。したがって、図２の定電流発生回路の構成を有することで、温度補償用抵抗Ｒ１をＲｓと近い値に設定し、出力電流Ｉｏの温度依存を抑制することが可能になる。すなわち、ＲｓとＲ１とを極力近い値にすることができるため，レイアウト面積縮小の観点から特に有効である。

【００５０】なお、本発明に係る定電流発生回路は、出力用トランジスタＴｒ１と電圧基準用トランジスタＴｒ２のベースが接続されかつ互いのエミッタがＧＮＤに接続され、前記トランジスタＴｒ１、Ｔｒ２のベースとエミッタ間に負の温度係数を有する抵抗Ｒｓが接続された定電流発生回路において、前記トランジスタのエミッタとＧＮＤの間に温度補償用素子を有するように構成してもよい。

【００５１】また、本発明に係る定電流発生回路は、上記構成において、出力用トランジスタＴｒ１のエミッタとＧＮＤ間に温度補償用素子を設けるように構成してもよい。

【００５２】上記の構成によれば、出力用トランジスタＴｒ１のエミッタとＧＮＤ間に温度補償用素子を追加、具備することで、定電流発生回路の出力電流温度に対する変化を抑制することができる。このような、ＶＢＥ電圧を基準とする電流発生回路は、受光増幅回路の高速化のため、抵抗がマイナスの温度係数を有する高速プロセスおいて、出力用トランジスタＴｒ１のエミッタとＧＮＤ間に温度補償用素子を有することで、その出力電流の温度に対する変化を抑制可能になる。

【００５３】また、本発明に係る定電流発生回路は、上記構成において、前記出力用トランジスタＴｒ１のエミッタとＧＮＤ間に第１の温度補償用素子を設け、かつ、電圧基準用トランジスタＴｒ２のエミッタとＧＮＤ間に第２の温度補償用素子を設けるように構成してもよい。上記の構成によれば、より高い温度補償効果を得ることができる。このような，電圧基準用トランジスタＴｒ２のエミッタとＧＮＤ間に温度補償用素子を併せ持つことで、Ｒ１を抵抗Ｒｓと近傍の抵抗値にすることが可能となり、より安定した定電流発生回路の出力電流の温度に対する抑制を得ることができる。

【００５４】また、本発明に係る定電流発生回路は、上記構成において、前記温度補償用素子が抵抗から成るように構成してもよい。

【００５５】また、本発明に係る定電流発生回路は、上記構成において、前記温度補償用素子である抵抗は，抵抗Ｒｓと同一形状の複数の抵抗を並列接続してなりかつ抵抗Ｒｓと隣接して配置されているように構成してもよい。

【００５６】

【発明の効果】以上のように，本発明の定電流発生回路は、出力用トランジスタのエミッタとＧＮＤとの間に第１の温度補償用素子が設けられた構成である。

【００５７】これにより、各トランジスタのベース－エミッタ間電圧の温度依存性と第１の温度補償用素子の温度依存性とで互いに相殺され、全体として出力電流の温度依存性を小さくすることができる。それゆえ、出力電

流の温度依存性を効果的に減少させることができるという効果を奏する。

【００５８】また、本発明の定電流発生回路は、上記の構成に加えて、上記第１の温度補償用素子が、上記抵抗Ｒｓと同一形状の複数の抵抗を並列接続してなり、かつ上記抵抗Ｒｓと隣接して配置されている構成である。

【００５９】これにより、抵抗Ｒｓと同じ製造プロセスで上記第１の温度補償用素子の形成が可能である。それゆえ、上記の構成による効果に加えて、簡単な構成で、かつ、精度よく、出力電流Ｉｏの温度依存性を低減させることができるという効果を奏する。

【００６０】また、本発明の定電流発生回路は、上記の構成に加えて、上記電圧基準用トランジスタのエミッタとＧＮＤとの間に第２の温度補償用素子が設けられた構成である。

【００６１】これにより、第２の温度補償用素子を備えることにより、上記第１の温度補償用素子に、十分大きな値の電圧をを加えることができる。それゆえ、上記の構成による効果に加えて、上記第１の温度補償用素子として、抵抗値の大きな素子を採用しても差し支えなくなり、材料の自由度や設計（素子の配置等）の自由度を広げることができるという効果を奏する。

【図面の簡単な説明】

【図１】本発明に係る定電流発生回路の一構成例を示す回路図である。

【図２】本発明に係る定電流発生回路の他の構成例を示す回路図である。

【図３】ピックアップ用受光増幅回路の構成例を示す回路図である。

【図４】従来の定電流発生回路の構成例を示す回路図である。

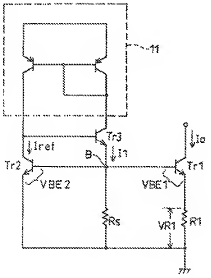
【図５】従来の定電流発生回路の構成例を示す回路図である。

【図６】ピックアップ用受光増幅回路のゲインー応答周波数特性を示すグラフである。

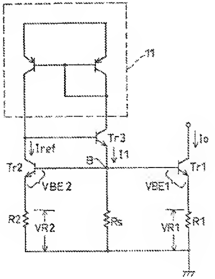
【符号の説明】

１１　能動負荷
Ｒ１　温度補償用抵抗（第１の温度補償用素子）
Ｒ２　温度補償用抵抗（第２の温度補償用素子）
Ｔｒ１　出力用トランジスタ
Ｔｒ２　電圧基準用トランジスタ

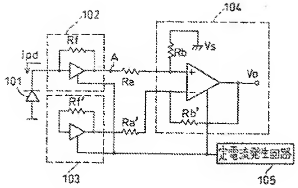
【図１】



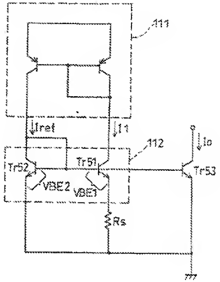
【図２】



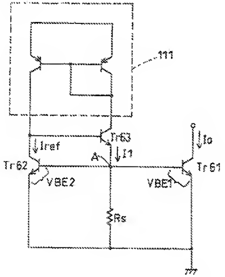
【図３】


102
104
Rf
Vs
Rb
Ipd
A
101
Ra
Vo
Rf'
Rb'
Ra'
定電流発生回路
103
105

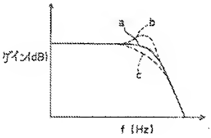
【図４】


111
Iref
I1
112
Io
Tr52
Tr51
Tr53
VBE2
VBE1
Rs

【図５】


111
Tr63
Iref
I1
Io
A
Tr62
Tr61
VBE2
VBE1
Rs

【図６】


a
b
c
ゲイン(dB)
f (Hz)

フロントページの続き

Fターム(参考)　5H420 NA31 NB03 NB22 NB24 NE23
5J090 AA03 AA43 AA56 AA59 CA02
CA81 CN01 FA08 FA10 FA20
FN01 FN06 FN09 HA08 HA25
HA43 HA44 HN20 KA09 KA12
KA47 MA19 MA21 TA03
5J091 AA03 AA43 AA56 AA59 CA02
CA81 FA08 FA10 FA20 HA08
HA25 HA43 HA44 KA09 KA12
KA47 MA19 MA21 TA03
5J092 AA04 AA43 AA56 CA02 CA81
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